MITSUBISHI ELECTRIC
Changes for the Better

for a greener tomorrow eco Changes

States and prospects of laser drivers for 250W and toward > 500W extreme ultraviolet (EUV) generation

Koji Yasui[1] and Jun-ichi Nishimae[2]
Mitsubishi Electric Corporation

[1]Head quarter, Factory Automation Systems Group, Tokyo, Japan
Yasui.Koji@aj.MitsubishiElectric.co.jp

[2]Advanced Technology R&D Center, Hyogo, Japan
Nishimae.Junichi@cw.MitsubishiElectric.co.jp

1. Who we are

Key machines supplier for emerging healthy markets

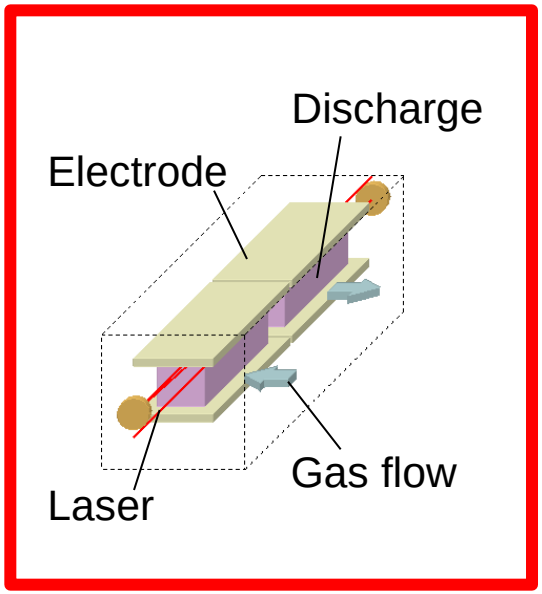
1. Who we are

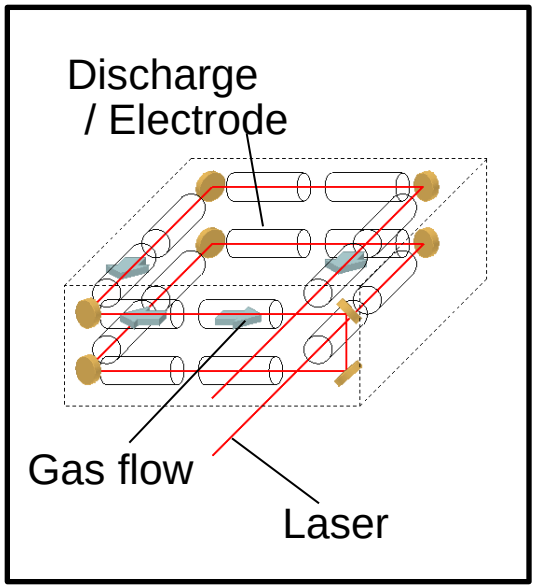
We are constructing eco-systems including a variety of in-house technologies, universities, and research institutes

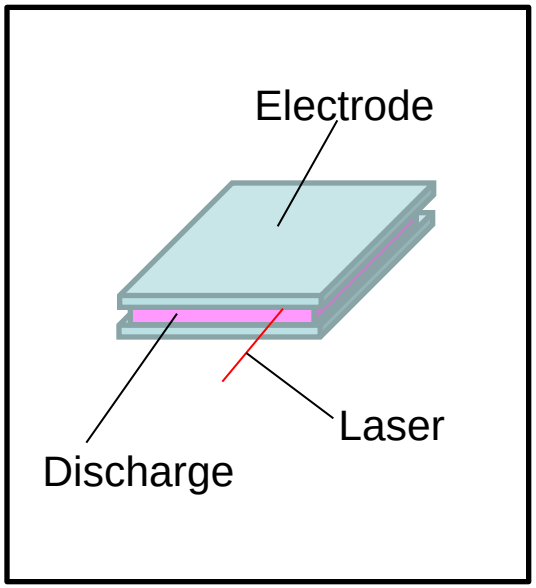
2. Advantage of our CO_2 lasers

2. Advantage of our CO_2 lasers

Transverse-gas-flow CO_2 lasers vs. other CO_2 lasers







1. Transverse-gas-flow

Low flow
Short length
Broad area

High-gain & Low-loss

2. Fast-axial-flow

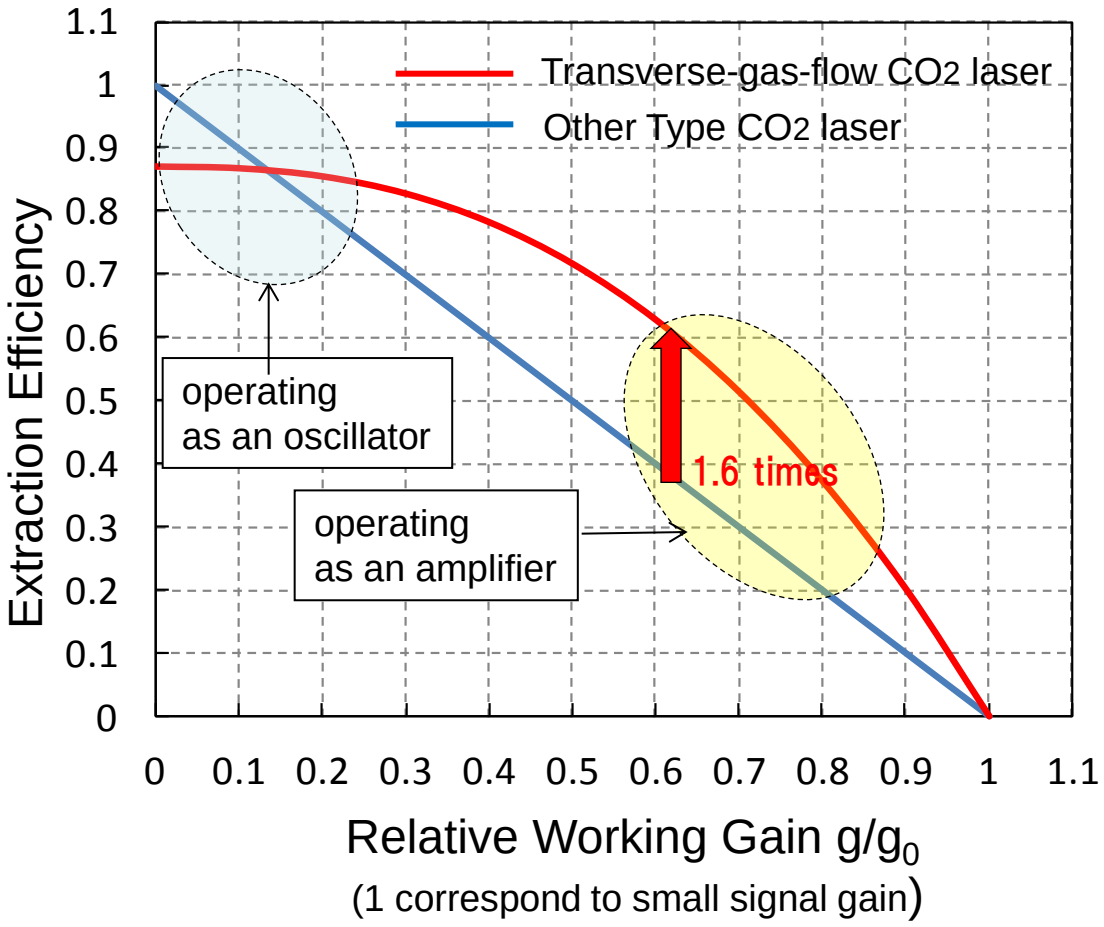
Fast flow
Long length
Small area

3. No-flow

No flow
Short length
Wide area

2. Advantage of our CO_2 lasers

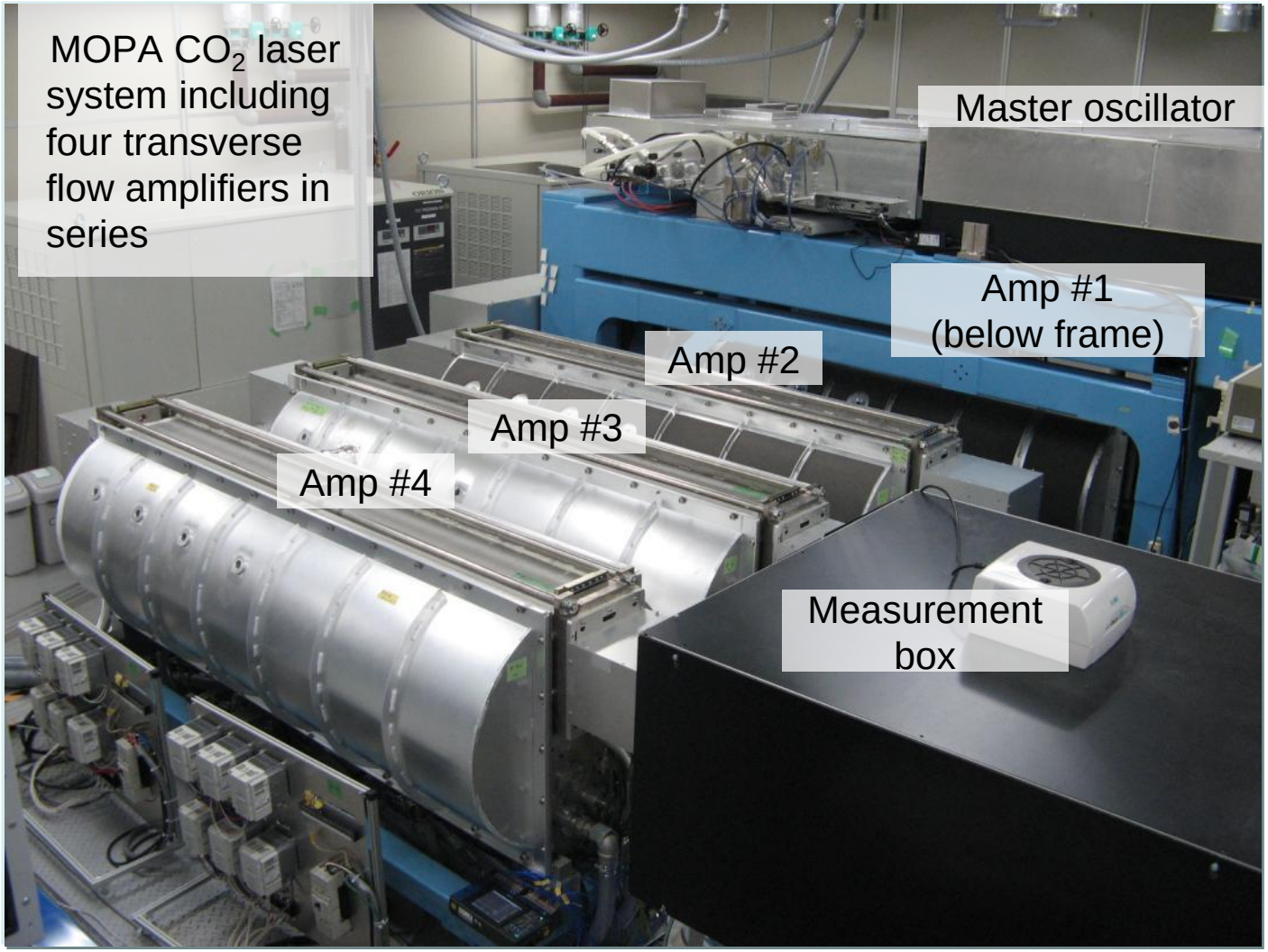
Theoretical calculation



3. Experimental results

3. Experimental results

Experimental setup



3. Experimental results

Operating conditions

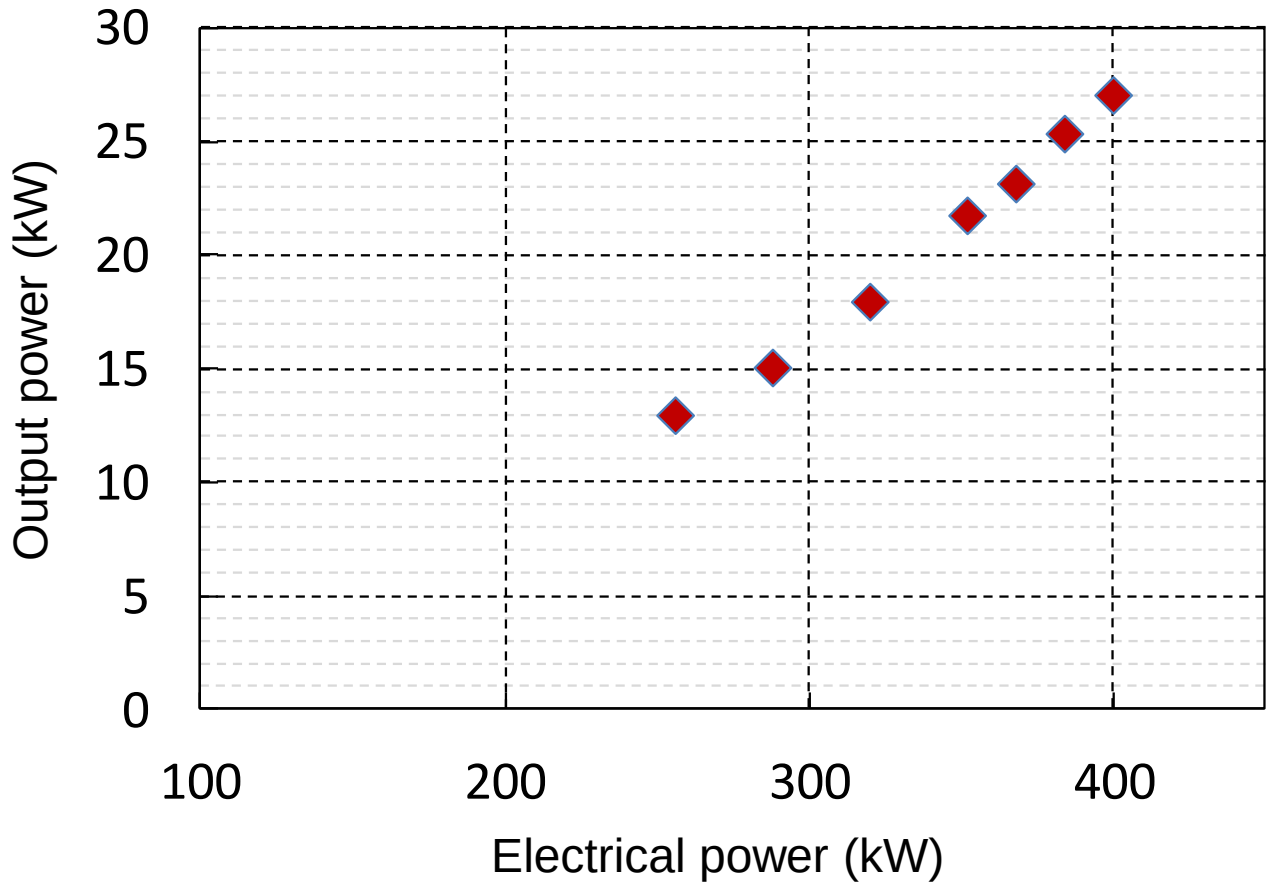
- Electrical input powers for discharge: 100 kW x4, duty 100%
- Laser input: 15 ns, 100 kHz

Master Oscillator	
Wavelength	10.6 um P(18,20,22,24)
Repetition frequency	100 kHz
Pulse duration	15 ns
Amplifiers	
Laser input	50 W max
Beam radius($1/e^2$)	6 mm@amp#1 , 15 mm@amp#2-4
Electrical input	100 kW max x4
Discharge duty	100%
Discharge volume	5x4x188 cm^3 x4
Gas pressure	7.0 kPa

3. Experimental results

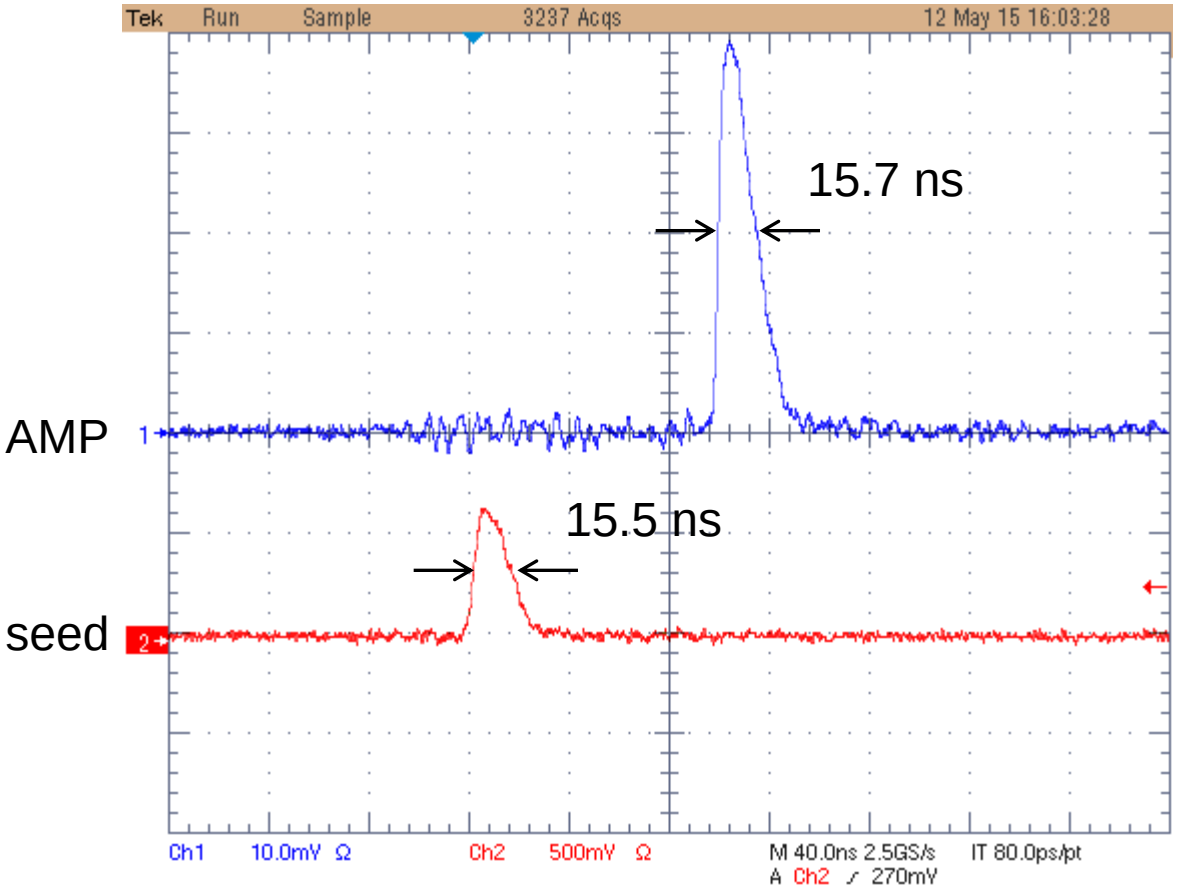
Four amplifiers driven by four-line oscillator

- Output power of 27 kW was demonstrated（duty 100%)



3. Experimental results

Pulse shape example



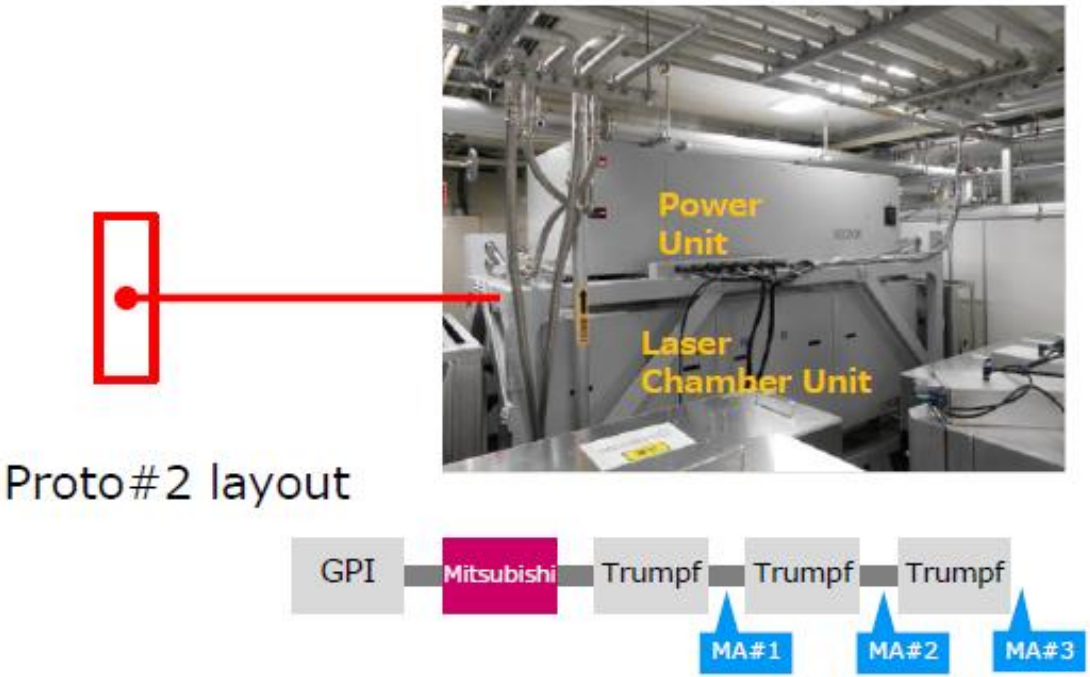
- Output pulse duration: 15.7 ns
- Linear amplification

3. Experimental results

16

Proto #2 System Layout

Mitsubishi pre-amplifier was installed in Proto #2 and performance was confirmed



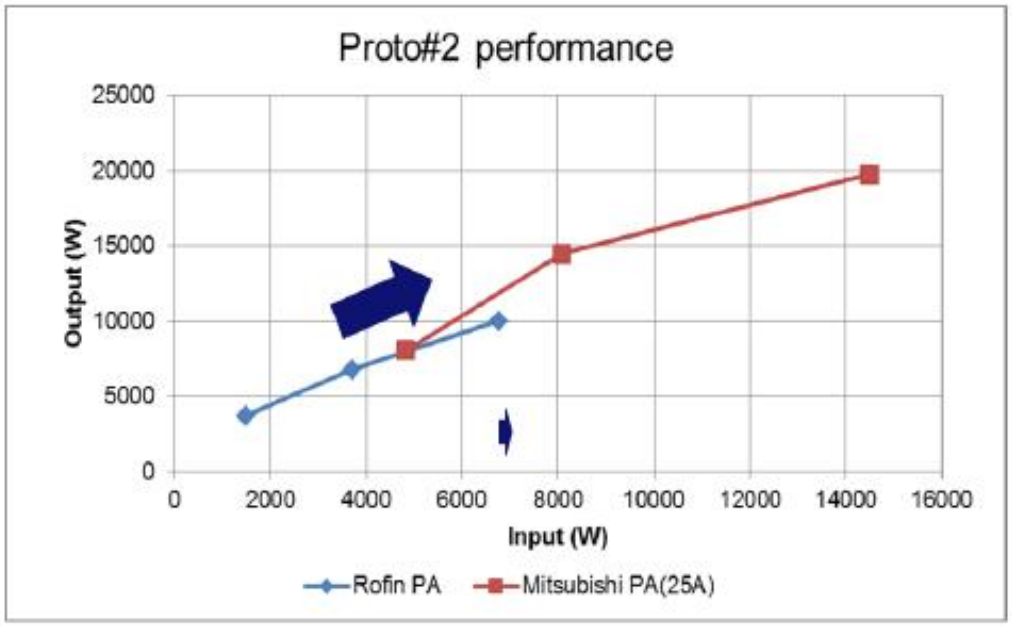
Proto#2 layout

3. Experimental results

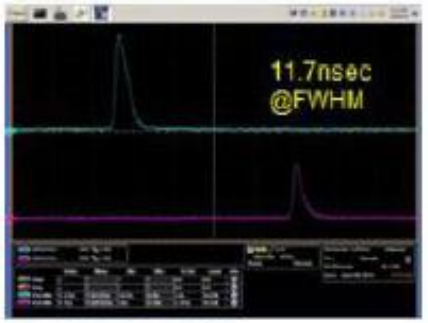
17

High Power EUV Source with Mitsubishi Pre-Amp

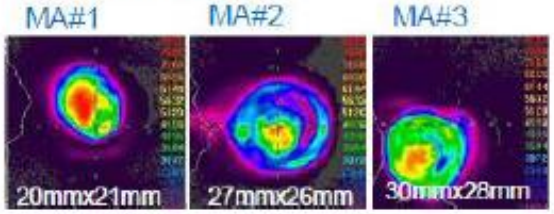
- 20kW output power was achieved with Driver laser system with Mitsubishi pre-amplifier
-



Pulse waveform



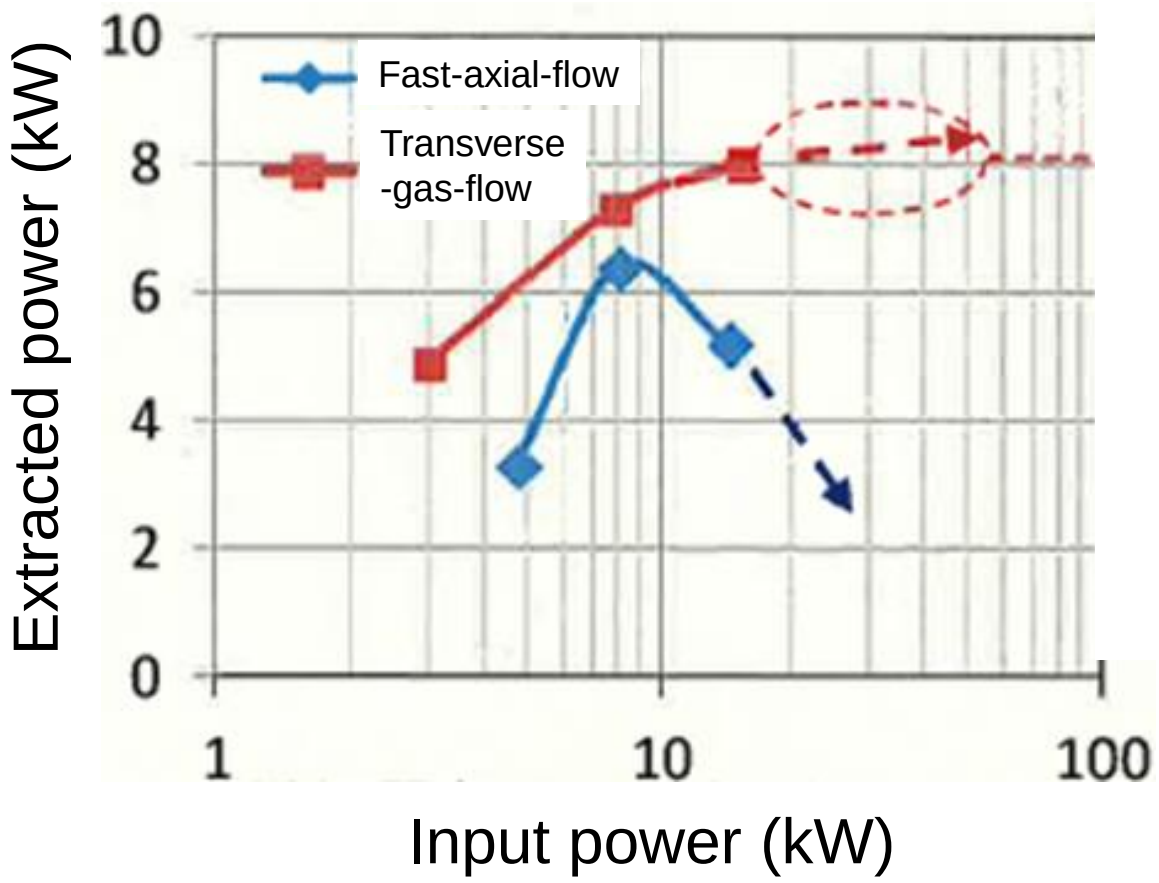
Beam Profile



4. Higher CO_2 power prospects

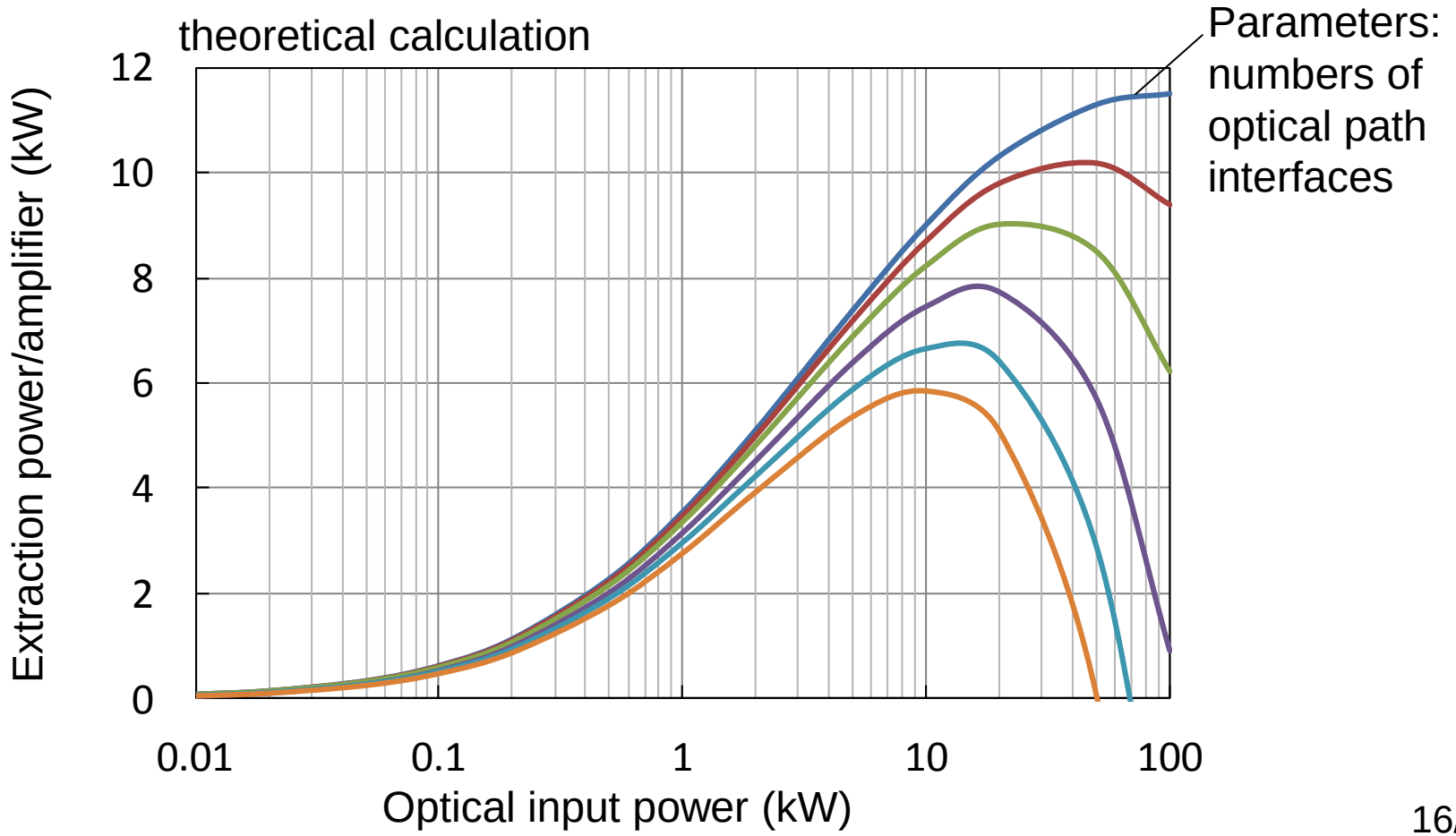
4. Higher CO_2 power prospects

Higher power extraction at higher input power for transverse-gas-flow CO_2 laser



4. Higher CO_2 power prospects

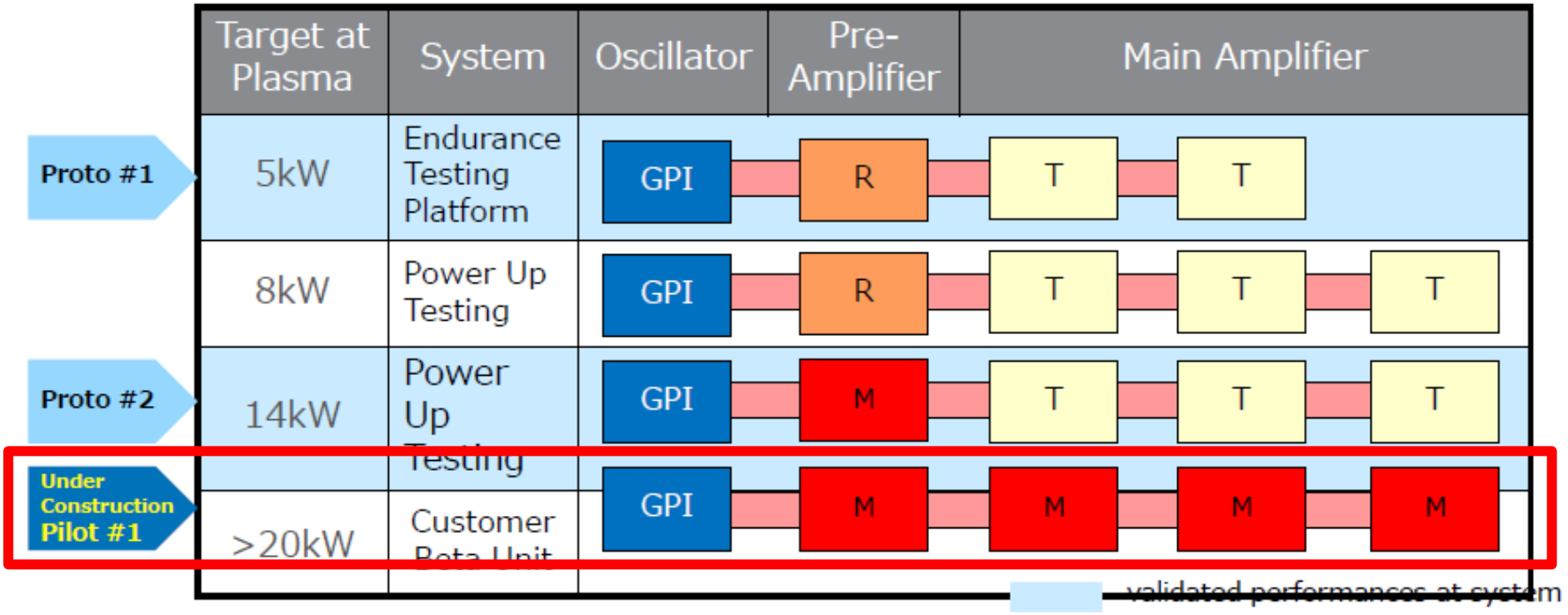
Optical path interfaces must be reduced for efficient operation at high input power



4. Higher CO_2 power prospects

CO_2 Driver Laser configuration for EUV Sources

8



4. Higher CO_2 power prospects

Proto Systems in Operation

Target System Specification

Operational Specification		Proto #1	Proto #2	Under construction Pilot #1
Target Performance	EUV Power	25 W	> 100 W	250 W
	CE	3%	4%	4%
	Pulse rate	100 kHz	100 kHz	100 kHz
	Output angle	Horizontal	62° upper (matched to NXE)	62° upper (matched to NXE)
	Availability	1 week operation	1 week operation	> 75%
Technology	Droplet generator	20 – 25 μm	20 μm	< 20 μm
	CO2 laser	> 8 kW	> 12 kW	25 kW
	Pre-pulse laser	picosecond	picosecond	picosecond
	Debris mitigation	validation of magnetic mitigation in system	10 days	> 30 days

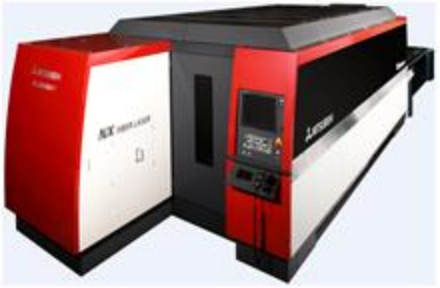
5. Higher EUV power prospects

5. Higher EUV power prospects

Opinions as a technology solution provider

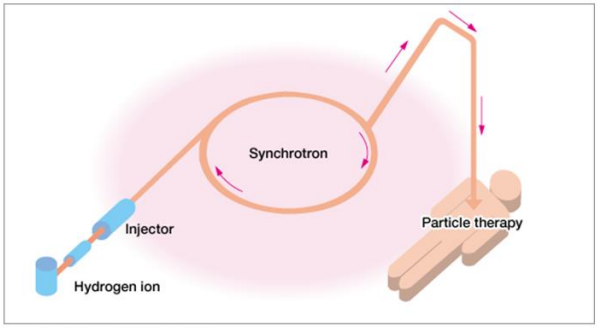
1. Industrial solid-state lasers

- Industrial fiber lasers are emerging
- Solid-state lasers, we need further enhancement of the efficiency to compete with CO_2 in TCO figures



2. Lasers based on synchrotron

- Medical applications are emerging
- Lasers based on synchrotrons need radical simpler configurations



Basic concept for particle therapy system

Synchrotron for proton beam

Synchrotron for carbon and proton beam

5. Higher EUV power prospects

Toward >500W or > 1kW EUV powers

1. If it is requested, we consider it is possible within the configuration we explained today

⇒ Add more CO_2 amplifiers and use Gigaphoton EUV technology

2. Another approach is to develop better reflective mirrors systems

⇒ Utilize academic brains: the University of Tokyo, supported by the Japanese government

http://www.ipst.s.u-tokyo.ac.jp/iccpt/

Acknowledgements

- The experiments were performed by research members at the advanced technology R&D center, Mitsubishi Electric corp. with valuable supports by Gigaphoton Inc.
- A part of this work was supported by The New Energy and Industrial Technology Development Organization (NEDO, Japan)

Thank you very much for your attention
Thank you again for your invitation to this workshop